Idaho State Department of Agriculture
Division of Agricultural Resources

Assessment of Water Quality in the Sunnyside Area, Washington County, Idaho: 2003 Update

Craig Tesch
Rick Carlson

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Introduction

The Idaho State Department of Agriculture (ISDA) Sunnyside monitoring project began in November 2002 as a result of citizen concerns of possible ground water contamination in the area surrounding a confined animal feeding operation (CAFO) and onion disposal site (Figure 1). Nutrients, common ions, dissolved metals, isotopes, and bacteria were evaluated during ISDA's testing in the Sunnyside area in November 2002. Laboratory results indicated a majority of wells (73%) in the project area had nitrate-nitrogen (NO_3-N) concentrations that exceeded the Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL)[1] of 10 milligrams per liter (mg/L) for NO_3-N. In addition, a majority of wells (58%) had $d^{15}N$ isotope values that suggested an animal or human waste source of NO_3-N.

ISDA conducted follow-up water testing in the Sunnyside area in April 2003. An additional four wells east of Highway 95 were sampled; these included two domestic wells, a dairy farm well, and a well supplying water to a school. Laboratory results indicated a majority of wells (69%) in the project area had NO_3-N concentrations that exceeded the EPA MCL of 10 mg/L for NO_3-N. In addition, a majority of wells (80%) had $d^{15}N$ isotope values that suggested an animal or human waste source of NO_3-N.

Previous ISDA Water Program findings have resulted in recommendations to improve the existing CAFO facility for water quality protection (Tesch, 2003). A majority of these recommendations have been implemented. Ground water monitoring will continue to assist with these efforts.

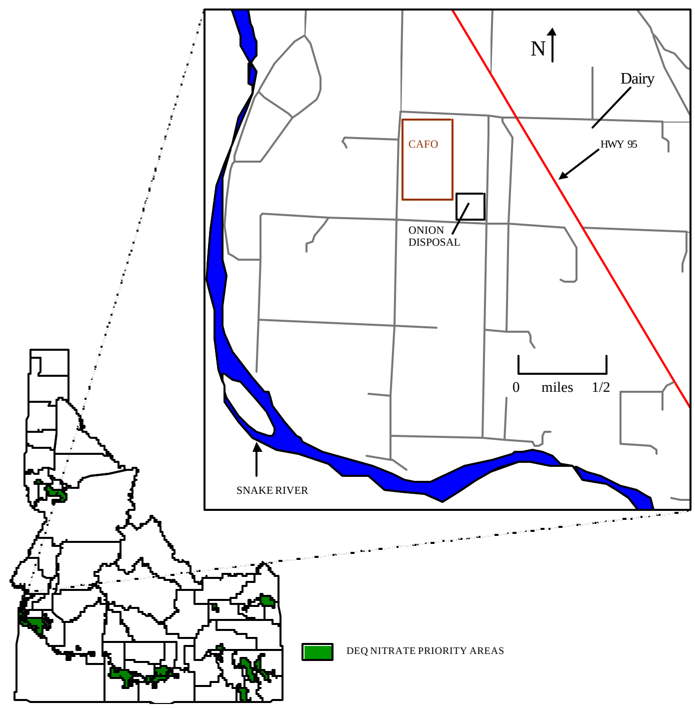


Figure 1. Sunnyside project area and location of DEQ nitrate priority areas.

Methods

To establish this local monitoring project, ISDA selected domestic wells up, down, and side gradient of the CAFO and onion disposal site and coordinated with homeowners to conduct ground water sampling. The 22 wells tested in November 2002 were re-sampled in April 2003, along with an additional four wells east of Highway 95. The four wells included two domestic wells, a dairy farm well, and a well supplying water to a school. The CAFO freshwater outlet drain was also sampled. All sampling was conducted after a quality assurance project plan (QAPP) was established. Permission was granted by the land owners prior to sampling.

[1]MCLs represent the EPA health standard for drinking water.

Nutrients, common ions, dissolved metals, isotopes, bacteria, and limited pharmaceuticals were evaluated during ISDA's testing. All sample collection followed the established ISDA QAPP for preservation, handling, storage, and shipping. Field quality assurance/quality control protocols consisted of duplicate samples (at 10% of the sample load) along with blank samples (one set per sampling event). Field blanks consisted of laboratory grade deionized water. The blank samples were used to determine the integrity of the field team's sample handling, the cleanliness of the sample containers, and the accuracy of the laboratory methods. Samples were sent to the University of Idaho Analytical Sciences Laboratory (UIASL) in Moscow, Idaho.

UIASL conducted tests for nitrate, nitrite, ammonia, orthophosphorus, chloride, sulfate, bromide, and fluoride using EPA Methods 300.0 and 350.1. UIASL also conducted tests for alkalinity and dissolved metals using EPA Methods 310.1 and 200.7. Internal laboratory spikes and duplicates were also completed as part of UIASL's quality assurance program.

Bacteria samples were analyzed by the State of Idaho Health and Welfare Laboratory in Boise, Idaho. Isotope samples were collected, frozen, and shipped to the North Carolina State University Stable Isotope Laboratory, in Raleigh, North Carolina for analysis.

Description of Project Area

The Sunnyside project encompasses an approximately one mile wide and three mile long area of agricultural, commercial, and residential land adjacent to the Snake River (Figure 1). Land use in the area consists of irrigated agricultural fields, a confined animal feeding operation, a dairy operation, an onion disposal site, commercial businesses, and rural housing. The major crop in the area is alfalfa. Additional crops include wheat, corn, and onions. Feedlot and dairy manure is applied to some agricultural fields within the project area.

Shallow ground water conditions exist across this area. Typically, depths to ground water are less than 20 feet. A potential source of recharge to this shallow system comes from applied irrigation waters. Shallow subsurface alluvial deposits (primarily sands and gravels) conducive to leaching underlie the Sunnyside area. Potential sources for NO_3-N leaching to ground water in the area include cattle manure, land applications of manure, wastewater lagoons, applied nitrogen-based fertilizers, rotations of legume crops, and septic systems.

Hydrogeology

The Sunnyside area lies within the western Snake River Plain, which is a basin filled with sedimentary deposits and volcanic rocks. The sedimentary deposits make up the major portion of the shallow aquifer in the project area (Figure 2). Using data from well logs, the shallow aquifer is composed of clays, silts, sands, and gravels. The majority of these sediments accumulated during prehistoric and historic Snake River deposition (Newton, 1991). Coarse-grained channel-type deposits may exist across the project area constituting preferential pathways for ground water flow and contaminant migration.

A geologic cross-section has been constructed using well logs from the project area (Figure 2). A layer of clay, approximately 15 feet in thickness, overlies a sand and gravel aquifer that varies from a minimum nine feet in thickness to an unknown maximum. A majority of wells are screened in this sand and gravel zone. A thick layer of blue clay underlies the shallow sand and gravel aquifer. The blue clay separates the shallow alluvial aquifer from the deeper sedimentary aquifer (Newton, 1991).

Horizontal ground water flow directions in the project area were determined by contouring static water level measurements using Surfer™ computer software (Figure 3). Surveying of well head elevations, along with static water level measurement, was conducted by ISDA at a majority of project wells. Figures 3(a) and 3(b) illustrate ground water levels and flow direction in January 2003 and July 2003, respectively. Water levels used to create the flow diagrams in Figure 3 show a mean decrease in water level of 1.1 feet from January to July. General ground water movement is toward the Snake River, an area of probable ground water discharge. The potentiometric surface does correspond with known ground water movement characteristics and theory.

Ground water flow direction appears to correspond to topographic slope, another characteristic common to shallow ground water. The general direction of ground water movement is west and southwest (Figure 3). Ground water flow velocity is estimated to be 2.4 ft/day in January 2003 and 2.6 ft/day in July 2003.

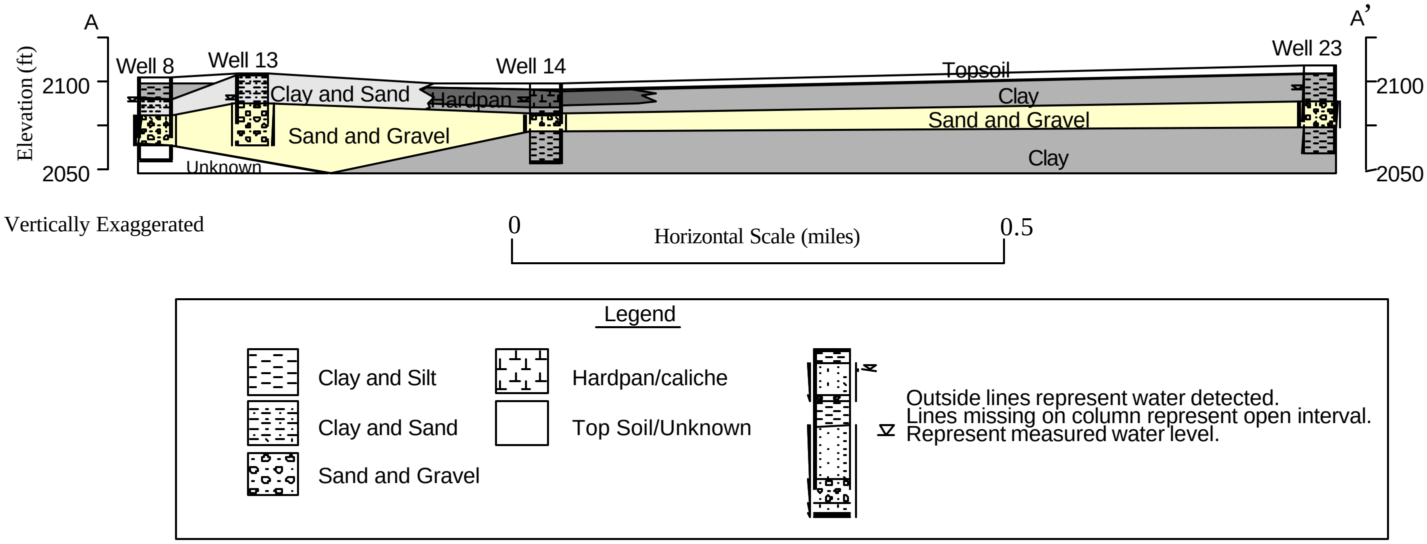


Figure 2. Geologic cross-section of Sunnyside area (Tesch, 2003). See Figure 3(a) for cross-section location.

Results

Sampling results indicate NO_3-N impacts have occurred to the shallow alluvial aquifer. Results are summarized and presented in the following sections.

Nitrate

ISDA conducted NO_3-N testing of 22 wells during November 2002 and 26 wells in April 2003 (Table 1). The CAFO freshwater outlet drain and the Snake River slough were also tested for nitrates in November 2002. Results of ground water sampling indicate a maximum concentration of 37 mg/L in November 2002 and

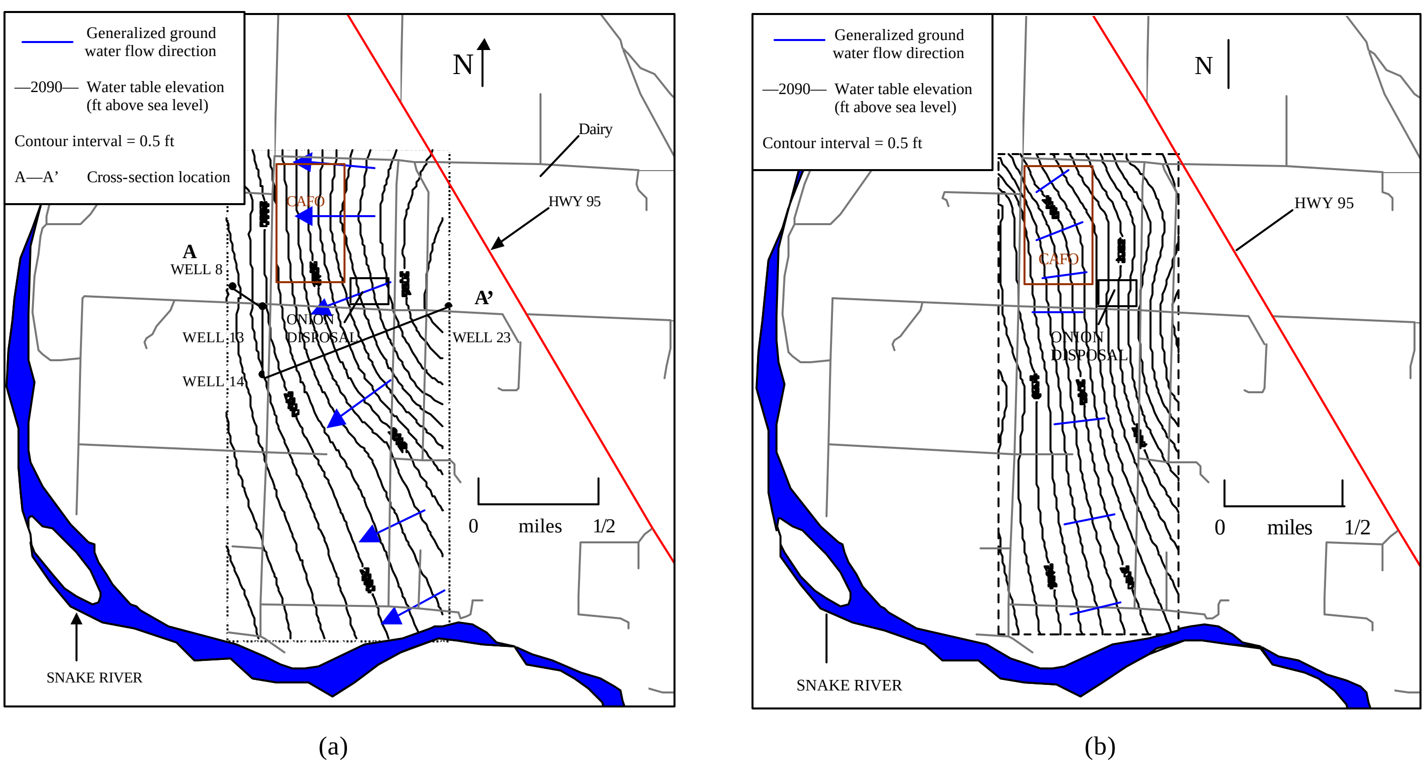


Figure 3. Ground water flow maps for (a) January 2003 and (b) July 2003. Cross-section location for Figure 2 is indicated on Figure 3(a).

43 mg/L in April 2003 (Table 1). The EPA MCL health standard of 10 mg/L was exceeded in 73% of the wells in November 2002 and 69% of wells in April 2003. The median nitrate value for all wells was 13.5 mg/L in April 2003 compared to 14.0 mg/L in November 2002.

Nitrate-nitrogen concentrations are most elevated in the areas west, or downgradient, of the CAFO and east, or upgradient, of the onion disposal site (Figure 4). The number of detections over 10 mg/L are of concern because of potential health risks.

Table 1. Distribution of nitrate concentrations in November 2002 and April 2003.

Concentration Range (mg/L)	November 2002	April 2003
	# wells (% wells)	# wells (% wells)
0.0 to 10.0	6 (27.3%)	8 (30.8%)
10.0 to 20.0	8 (36.3%)	9 (34.6%)
20.0 to 30.0	6 (27.3%)	6 (23.1%)
> 30.0	2 (9.1%)	3 (11.5%)
Total	22 (100%)	26 (100%)
Mean Value	15.9 mg/L	15.2 mg/L
Median Value	14 mg/L	13.5 mg/L
Maximum Value	37 mg/L	43 mg/L

Nitrogen Isotopes

The ratio of the common nitrogen isotope ^{14}N to its less abundant counterpart ^{15}N relative to a known standard (denoted d^{15}N) can be useful in determining sources of NO_3-N. Common sources of NO_3-N in ground water are applied commercial fertilizers, animal or human waste, and organic nitrogen within the soil. Each of these NO_3-N source categories has a potentially distinguishable nitrogen isotopic signature. The typical d^{15}N range for fertilizer is –5 per mil ($^0/_{00}$) to +5 $^0/_{00}$, while typical values for waste sources are greater than +10 $^0/_{00}$. d^{15}N values between +5 $^0/_{00}$ and +10 $^0/_{00}$ can indicate an organic or mixed source (Kendall and McDonnell, 1998).

Use of nitrogen isotopes as the sole means to determine NO_3-N sources should be done with great care. d^{15}N values in ground water can be complicated by several reactions (e.g., ammonia volatilization, nitrification, denitrification, plant uptake, etc.) that can modify the d^{15}N values (Kendall and McDonnell, 1998). Furthermore, mixing of sources along shallow flowpaths makes determination of sources and extent of denitrification very difficult (Kendall and McDonnell, 1998).

ISDA conducted d^{15}N testing to use it as a possible indicator of NO_3-N source(s) in the ground water. Nineteen wells, the Snake River slough, and the CAFO lagoon were selected for testing in November 2002; twenty wells were selected in April 2003. Wells chosen for nitrogen isotope testing had elevated NO_3-N concentrations. The samples were sent to the North Carolina State University Stable Isotope Lab for d^{15}N analysis.

In November 2002, 11 wells had values that suggested an animal or human waste source (Table 2), one suggested a fertilizer source, and seven had d^{15}N values that indicated an organic or mixed source of nitrates. The 11 wells that suggested an animal or human waste source are in areas downgradient and upgradient from the CAFO (Figure 5a).

In April 2003, 16 wells had values that suggested an animal or human waste source (Table 2), zero suggested a fertilizer source, and four had d^{15}N values that indicated an organic or mixed source of nitrates. The 11 wells that suggested an animal or human waste source are in areas downgradient and upgradient from the CAFO (Figure 5b).

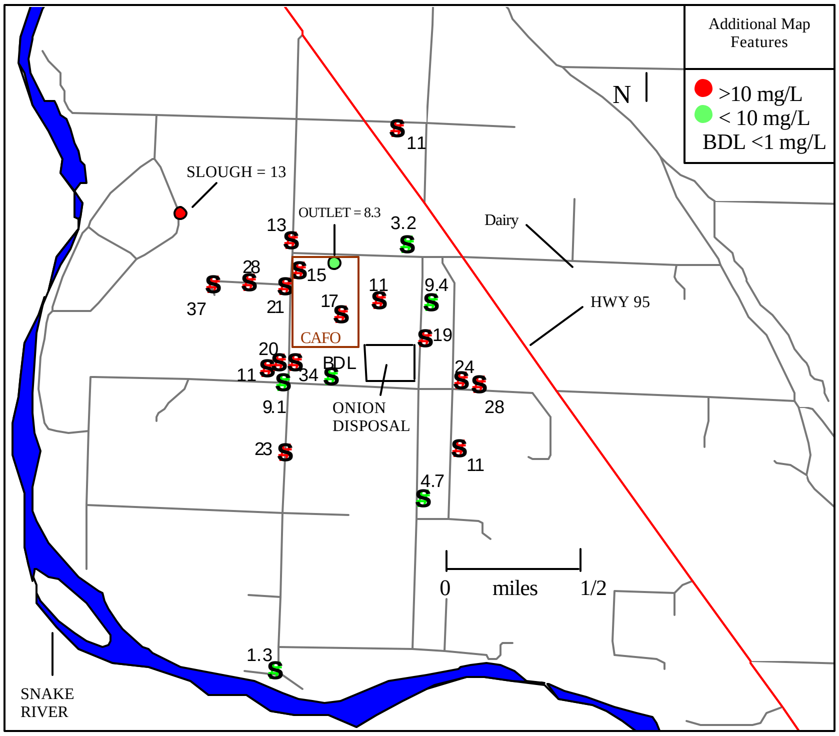
Table 2. d^{15}N results for Sunnyside monitoring project, November 2002 and April 2003.

d^{15}N Values ($^0/_{00}$)	Potential NO_3-N Source	November 2002	April 2003
		# wells (% wells)	# wells (% wells)
-5 to +5	Commercial Fertilizer	1 (5.3%)	0 (0%)
+5 to +10	Organic Nitrogen in Soil or Mixed Source	7 (36.8%)	4 (20%)
>10	Animal or Human Waste	11 (57.9%)	16 (80%)
Total		19 (100%)	20 (100%)

Oxygen Isotopes

Denitrification is the removal of nitrogen from compounds, by bacteria in the soil, which results in the escape of nitrogen into the air. Analysis of both d$^{18}O_{NO3}$

(a)



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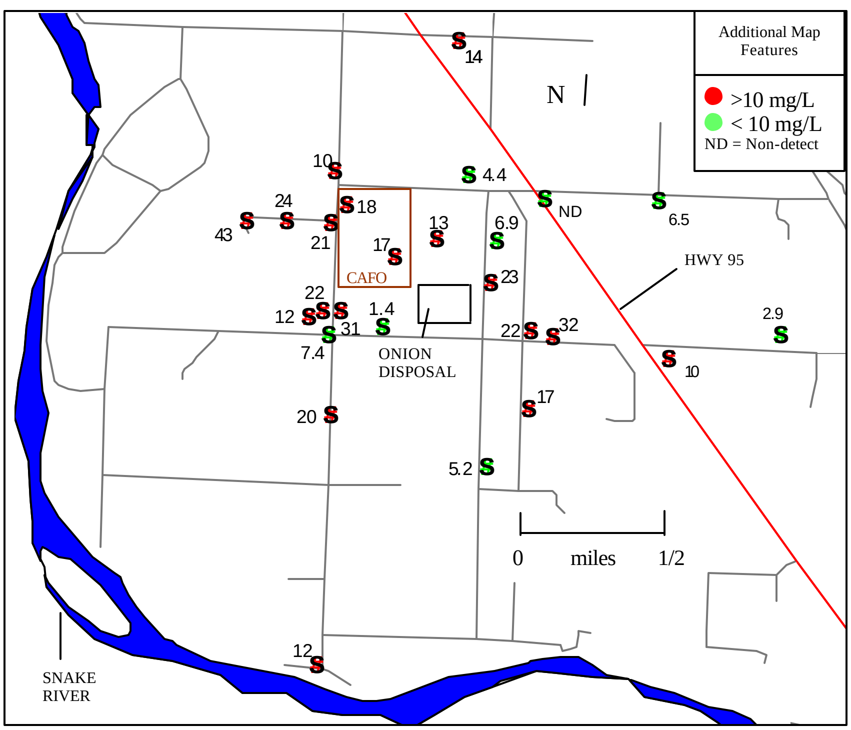
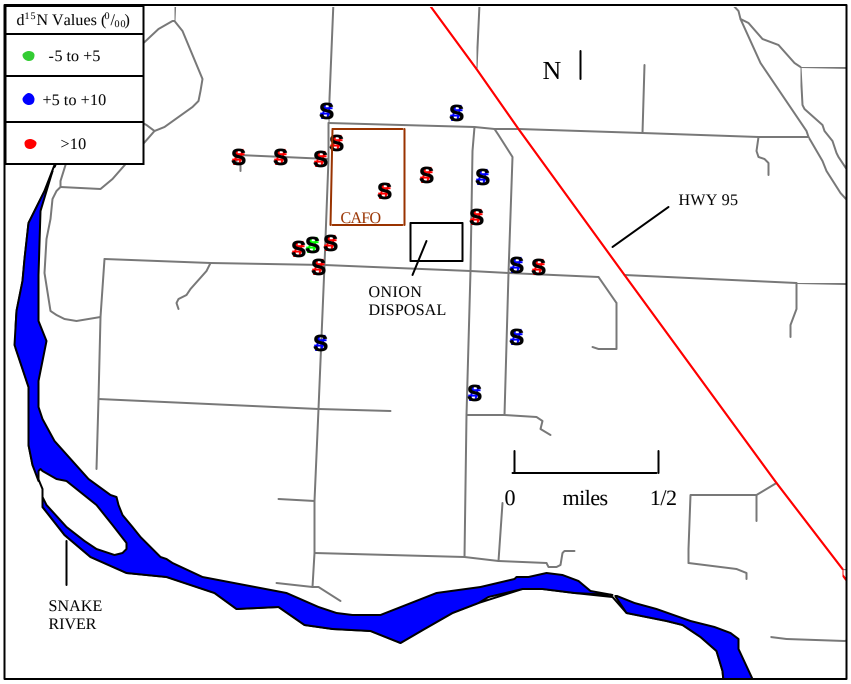


Figure 4. Nitrate concentrations in (a) November 2002 at 22 wells, CAFO freshwater outlet drain, and Snake River slough and (b) April 2003 at 26 wells.

(a)



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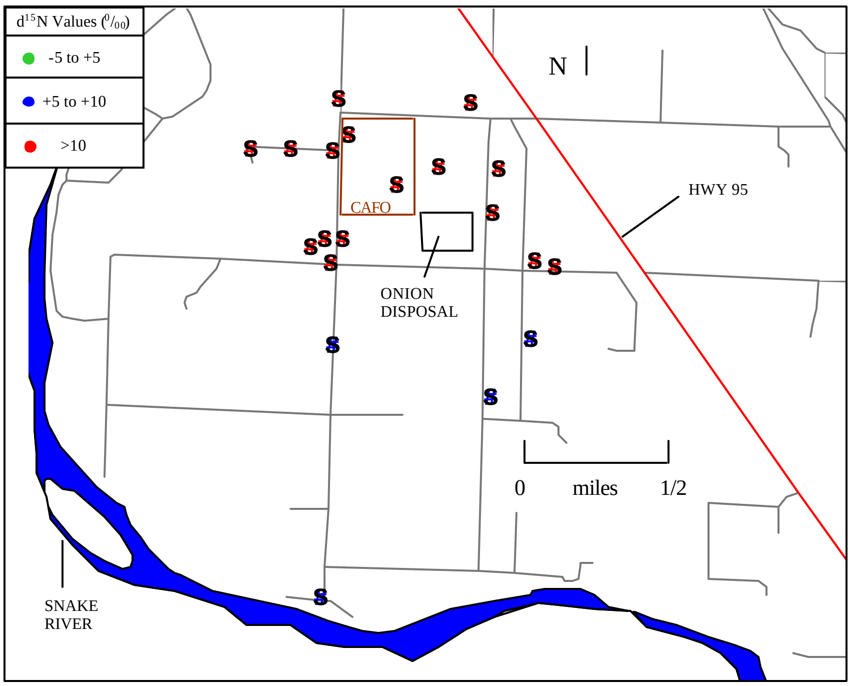
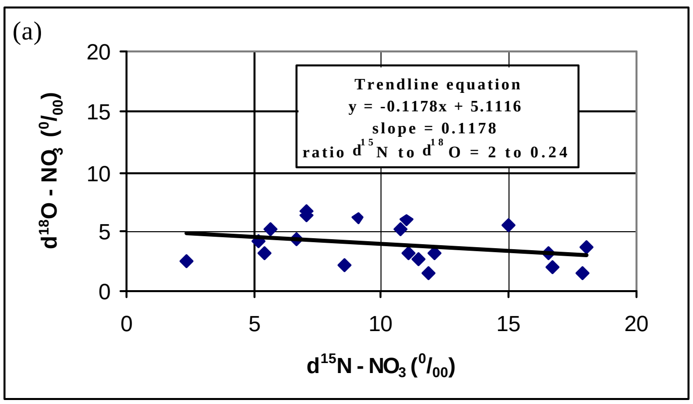


Figure 5. d[15]N values in (a) November 2002 at 19 wells and (b) April 2003 at 20 wells.

and d^{15}N of nitrate allows denitrification effects to be distinguished from mixing of sources. Amberger and Schmidt (1987) reported that denitrification results in enrichment in both d$^{18}O_{NO3}$ and ^{15}N of the residual nitrate. This dual isotope approach takes advantage of the observation that the ratio of the enrichment in ^{15}N to the enrichment in d$^{18}O_{NO3}$ in residual nitrate during denitrification appears to be about 2:1 (Amberger and Schmidt, 1987).

Wells in the project area that were tested for d^{15}N were also tested for d$^{18}O_{NO3}$. A linear trendline matched to data from a plot of d^{15}N versus d$^{18}O_{NO3}$ (Figure 6) shows a ratio much less than 2:1 for both November 2002 and April 2003. This indicates that d^{15}N values over +10 $^0/_{00}$ are due to animal or human waste sources and not denitrification processes.



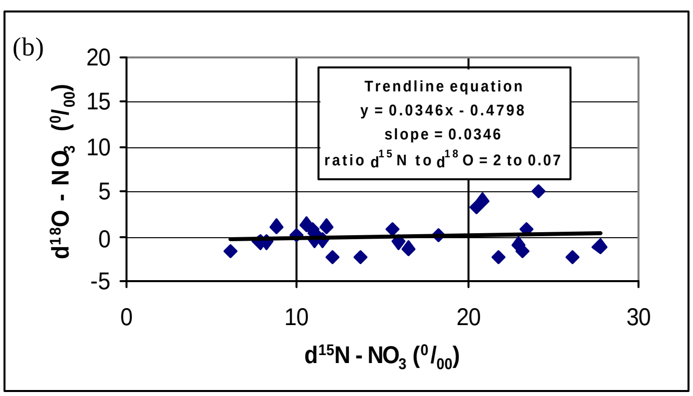


Figure 6. Plot of d^{18}O versus d^{15}N for (a) 19 wells in November 2002 and (b) 26 wells in April 2003.

Ammonia

Ammonia is a part of the nitrogen cycle. Most nitrogenous materials in natural waters tend to be converted to nitrate, so all sources of combined nitrogen, particularly organic nitrogen and ammonia, should be considered as potential nitrate sources. Ammonia is oxidized by bacteria (e.g., Nitrosomonas) sequentially to nitrite and nitrate through a process called nitrification. The ground water conditions where ammonia is found may not have enough oxygen to convert the ammonia to nitrate.

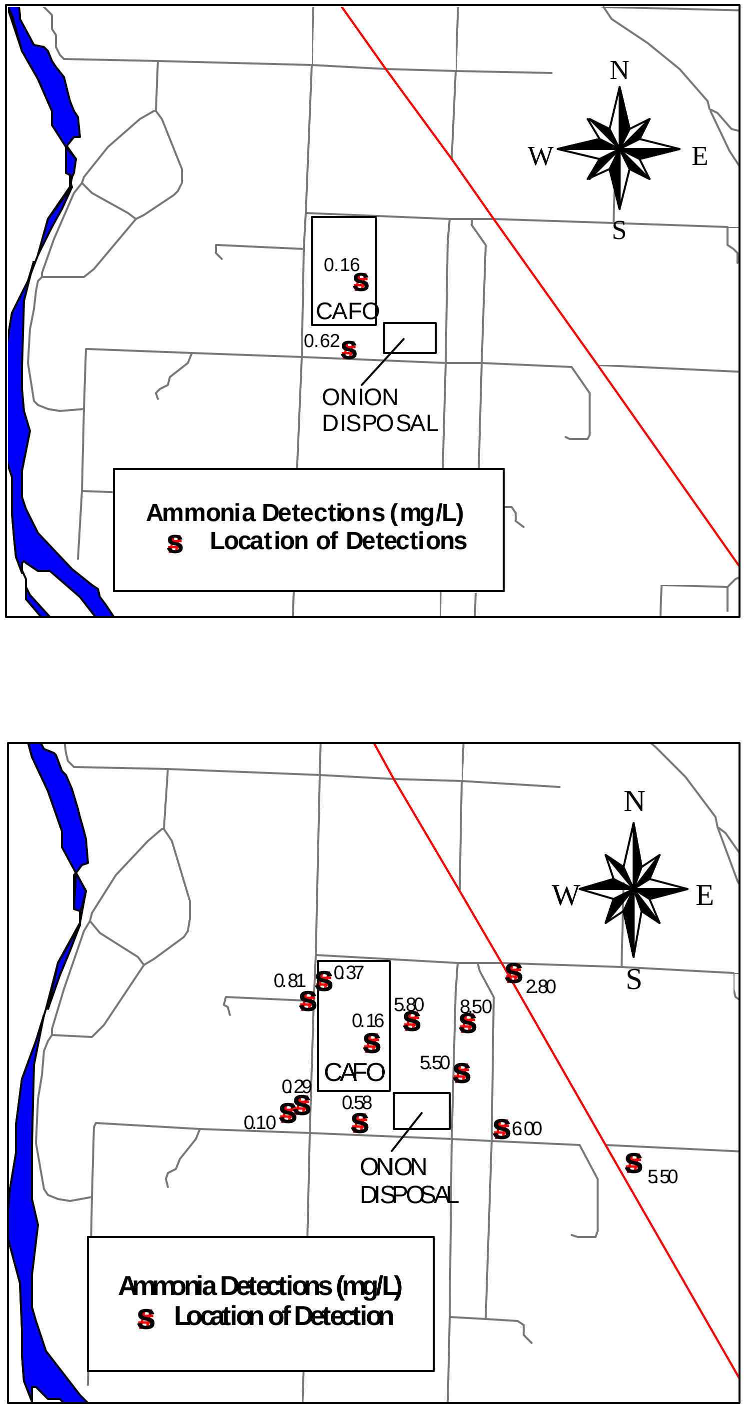
Ammonia levels ranged from non-detect (<0.005 mg/L) to 0.62 mg/L in November 2002 and non-detect (<0.005 mg/L) to 8.50 mg/L in April 2003 (Figure 7). A health regulatory level for ammonia does not exist. Ammonia is a naturally occurring compound in ground water; however, elevated levels of ammonia in ground water are not common. Anthropogenic sources (e.g., manure, septic waste, fertilizer) can contribute to elevated levels.

The cull onion disposal site is also a potential source of elevated ammonia levels. A 1995 study on the landfill disposal of cull onions presented the following conclusions (Hutchings, 1995):

1) Well constructed and maintained cull onion landfills are not a major source of nitrate contamination to regional ground water resources while the cull onion material is saturated and anaerobic.
2) Large quantities of ammonium stored in the landfills may be converted to nitrate after the landfills dry and the residual cull onion material becomes aerobic. If this conversion occurs, the landfills may become a source for nitrate contamination of the underlying aquifer.
3) Nitrate concentrations below cull onion landfills increase during the initial two to three months of landfill operation, but decrease rapidly to below detection limit after the formation of a low conductivity organic lining. Nitrate concentrations remain below detection limit for at least four years because nitrification is inhibited in saturated (anaerobic) cull onion waste.
4) Ammonium concentrations below cull onion landfills increase from zero to as much as 400 mg ammonium-nitrogen (NH_4-N) per liter after the formation of the low conductivity organic lining and subsequent inhibition of nitrification.

Conclusions above, regarding nitrate, are supported by data from this project. The last large onion burial event

(a)



(b)

Figure 7. Ammonia detections in wells in (a) November 2002 and (b) April 2003.

occurred in the Sunnyside area in November 2000. The closest downgradient well from the onion disposal site (Figure 4a) exhibited nitrate values below detection limit in November 2002 and 1.4 mg/L in April 2003 (Figure 4b). Ammonia was detected, but at low levels, at the same well; 0.62 mg/L and 0.58 mg/L in November 2002 and April 2003, respectively.

Bacteria

Each well was tested for total coliform bacteria and Escherichia coli (E.coli) bacteria. Positive total coliform results may indicate the possibility of mammalian intestinal bacteria being present. Three wells tested positive for total coliform in November 2002, however, zero tested positive in April 2003. No wells tested positive for E. coli during both sampling events. The CAFO trough overflow drain tested positive for total coliform and E. coli in both November 2002 and April 2003; the drain has been sealed and is no longer in use.

Sources of bacteria in the ground water in November 2002 could be contaminated piping systems, septic tanks, domestic animal waste sources, or contaminated surface waters located near the wells sampled. Bacteria in the ground water could also be associated with nearby CAFO waste, waste handling systems, or lagoons.

Trilinear Diagrams

A trilinear diagram is a tool that compares the cations and anions from a water sample in an attempt to assign a water type name. The results from trilinear diagrams can be used to assess if the water samples originate from a single water type, or if multiple water types exist in an area. Results can ultimately be useful in determining ground water source areas.

November 2002 samples were analyzed for constituents necessary in developing trilinear diagrams; plots were produced using AquaChem™ computer software (Figure 8). The constituents were calcium, magnesium, sodium, potassium, chloride, sulfate, and bicarbonate. The anion plot (Cl, HCO_3, SO_4), Figure 8(a), shows that all wells except one have the characteristics of a bicarbonate type of water; the exception has no dominant type. The cation plot (Mg, Ca, Na+K), Figure 8(b), shows that 16 wells have the characteristics of a sodium-potassium type water, while six wells have no dominant water type. Sodium-potassium and bicarbonate water types exist at a majority of wells tested.

Sodium and Sulfate

Anthropogenic sources of sodium (Na) include road salt and animal wastes. Sodium is also a common chemical in minerals and is gradually released from rocks; concentrations therefore increase with time. All samples taken in November 2002 exceed the EPA guidance level of 20 mg/L for sodium (http://www.epa.gov/safewater/ccl/sodium.html).

Anthropogenic sources of sulfate (SO_4) include fertilizers and animal wastes. Sulfate is also commonly found in water, soil, and air. Combustion of fossil fuels release large amounts of sulfur into the air. Sulfur is oxidized to sulfate and deposited with precipitation. Gypsum can also be a natural source of elevated sulfate. Other sources of sulfur include the decomposition of organic matter and volcanoes. Fourteen of the 22 wells tested in November 2002 exceed the EPA secondary MCL of 250 mg/L for sulfate (http://www.epa.gov/safewater/sulfate.html).

Additional analysis of sodium and sulfate reveal groupings of wells with respect to sodium-sulfate ranges. Figure 9(a) demonstrates these groupings on a plot of sodium versus sulfate. Group 1 wells (Table 3) have the lowest sodium and sulfate values, while Group 3 wells have the highest values; Group 2 is midrange.

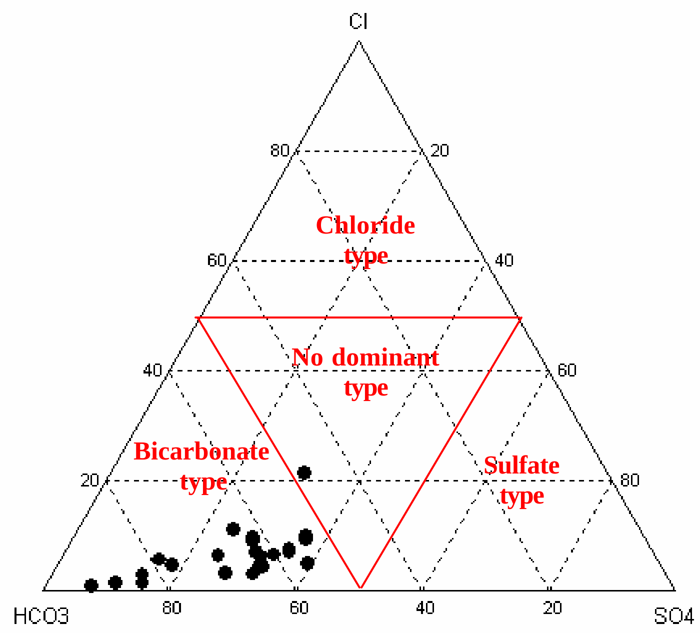
Table 3. Well grouping for sodium-sulfate analysis of November 2002 samples.

Well Group	# Wells	Na Range (mg/L)	SO_4 Range (mg/L)
Group 1	6	46-130	36-160
Group 2	11	160-360	200-350
Group 3	5	410-520	450-600

Plotting well groups (Table 3, Figure 9a) on a site map (Figure 9b) and comparing them to a nitrate contour map (Figure 10) and a ground water flow map (Figure 3) reveals relationships of wells with respect to nitrate sources. Group 3 wells are downgradient of the CAFO's south lagoon and have the following characteristics (from November 2002 results):

1) High sulfate, 450-600 mg/L.
2) High sodium, 410-520 mg/L.
3) High nitrate, 9.1-37 mg/L.

(a)



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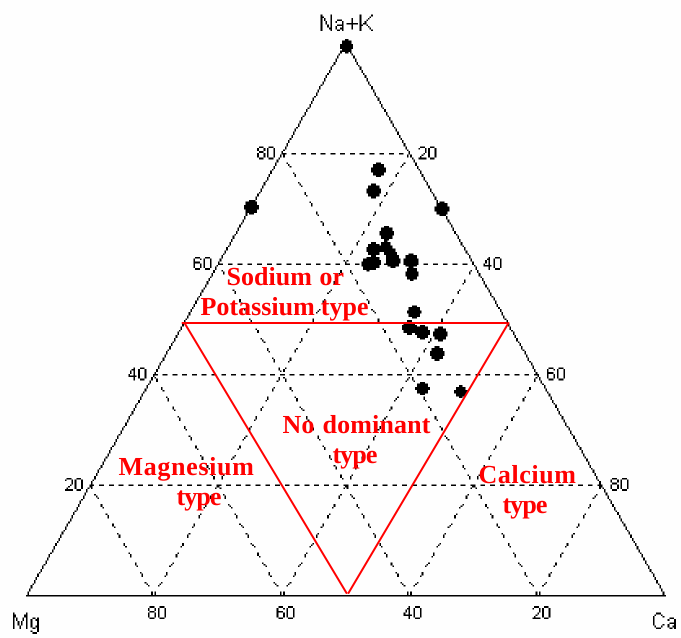
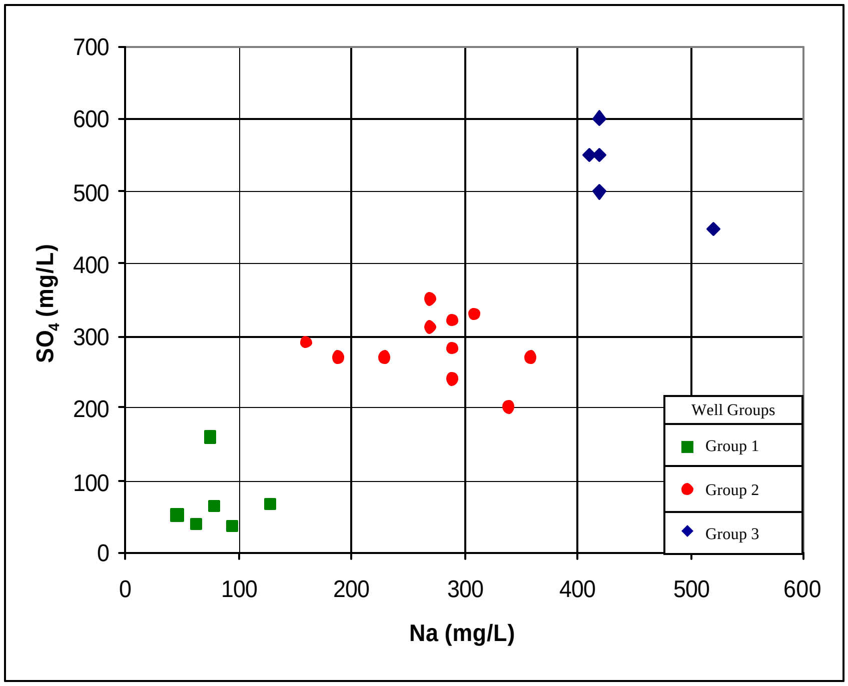


Figure 8. Trilinear diagrams indicating (a) anion and (b) cation water types. Black dots represent individual well samples in November 2002.

(a)



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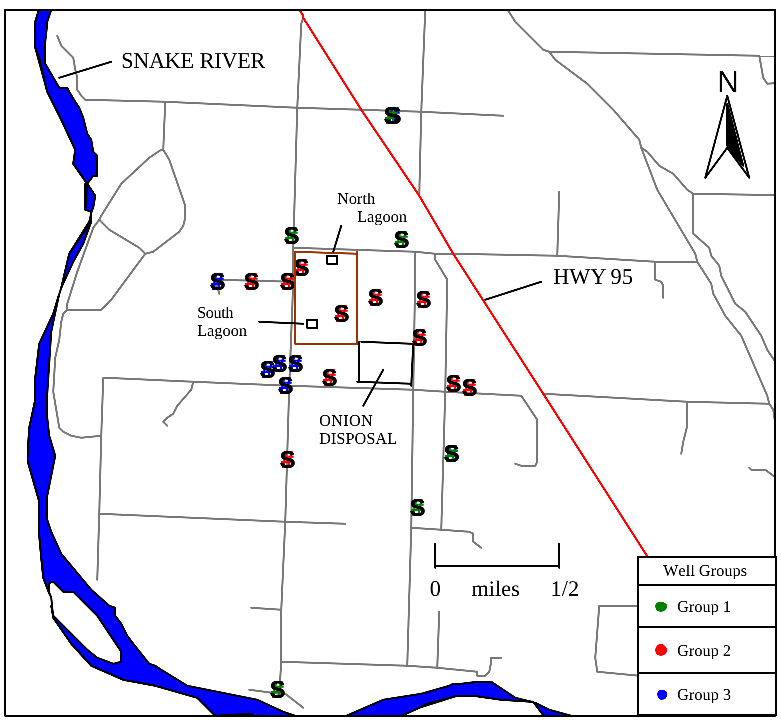

Figure 9. Sodium-sulfate distribution illustrated by (a) plot of sodium versus sulfate and (b) site map with well groupings from (a).

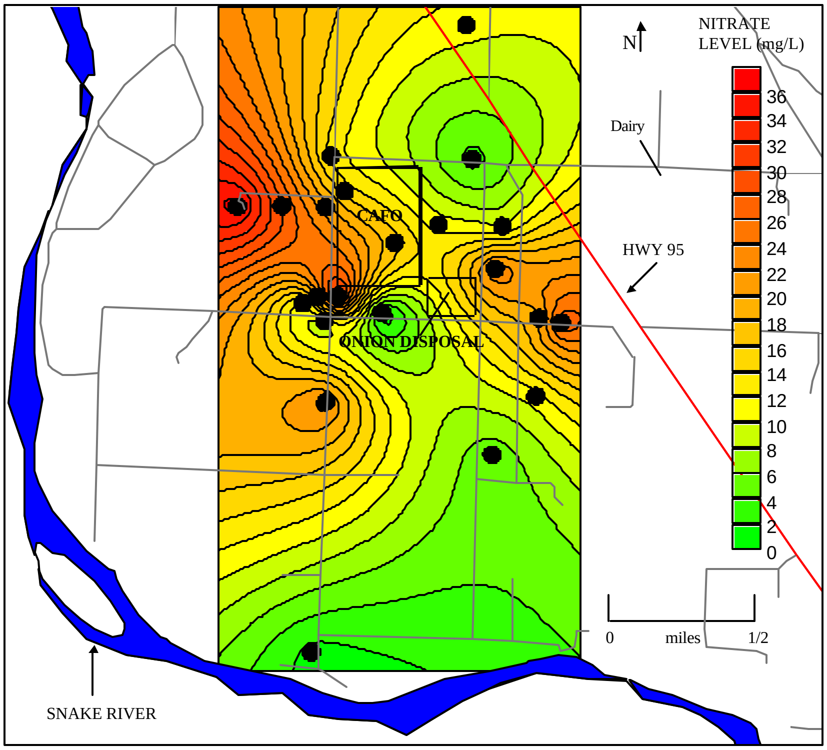

Figure 10. Kriged contour map of ground water nitrate concentrations in November 2002 from sampled wells (black dots) in the Sunnyside area (Tesch, 2003).

In addition, d[15]N values at four of the five wells indicate an animal or human waste source. Characteristics discussed above suggest that the south lagoon was a source of nitrate contamination. ISDA recommended the redesign of both lagoons to meet state standards. Both of the old CAFO lagoons were inspected before the construction of new lagoons, and it was found that the south lagoon was not lined; this supports the theory that the south lagoon was a source of nitrate contamination. Both lagoons have been redesigned and relined; they now exceed state standards.

Pharmaceutical Testing

Large livestock CAFO's require the use of pharmaceuticals (e.g., antibiotics, hormones) to prevent epidemics and increase the animal's rate of weight gain. Pharmaceuticals may end up in CAFO wastewater and may be transported to ground water (Lindsey, et. al., 2001).

Two water samples were analyzed for pharmaceuticals by the UIASL in February 2003. These included a grab sample taken from the CAFO wastewater lagoon and a ground water sample from a CAFO well. The two samples were extracted using a procedure developed by the United States Geological Survey (Lindsey, et. al., 2001). Samples were then analyzed using mass spectrometry. UIASL verified test results were provided to ISDA in September 2003. Detections of sulfamethizine and sulfadimethoxane, members of the sulfonamides class of antibiotics, were found in both samples (Table 4). The sulfonamides are commonly used antibiotics and are classified as synthetic antimicrobials. These findings suggest that the CAFO lagoon was interacting with and impacting ground water.

Table 4. Antibiotic test results for CAFO lagoon and well water in May 2003.

Matrix	Analyte Detected	Sample Concentration µg/L
Ground water well	Sulfamethizine	0.310
	Sulfadimethoxane	0.107
Lagoon water	Sulfamethizine	42.353
	Sulfadimethoxane	2.033

Conclusions

Ground water within the shallow alluvial aquifer of the project area is significantly impacted by NO_3-N. The high NO_3-N concentrations and the large number of NO_3-N detections within the project area are of concern. The Sunnyside area is highly vulnerable to ground water and surface water contamination due to (1) shallow ground water conditions, (2) shallow subsurface alluvial deposits, primarily sands and gravels, and (3) proximity to the Snake River.

In April 2003, 18 or 69% of the wells sampled exceeded the EPA MCL of 10 mg/L for NO_3-N; 9 or 35% of all wells exceeded 20 mg/L for NO_3-N. Areas having the highest NO_3-N concentrations are downgradient of the CAFO.

The large number of $d^{15}N$ values exceeding +10 $^{0}/_{00}$ suggest that animal and/or human waste sources are contributing to high NO_3-N concentrations. Oxygen isotope analysis indicates that $d^{15}N$ values over +10 $^{0}/_{00}$ are not artificially high from denitrification processes.

Sodium, sulfate, NO_3-N, and $d^{15}N$ values downgradient of the CAFO's south lagoon suggest the lagoon was a source of nitrate contamination. A detection of sulfamethizine and sulfadimethoxane in the CAFO ground water well also suggests transport of antibiotics to ground water from the previously unlined lagoon.

Elevated levels of ammonia and high nitrate values upgradient from the CAFO suggest other potential sources of nitrate contamination. These include septic systems and land applications of manure. Low level ammonia detections directly downgradient of the onion disposal site may indicate leaching of organic onion material under saturated, anaerobic conditions.

The extent of nitrate contamination in the area surrounding the CAFO was unknown prior to ISDA's water study in November 2002. ISDA made recommendations to the existing CAFO facility to improve water quality following the water study in November 2002; a majority of the recommendations have been followed. Improvements made by the CAFO facility, with the aid of ISDA and the Natural Resources Conservation Service, include:

- Berming to contain surface water runoff.
- Recycling of trough overflow water.
- Drainage of lagoons, evaluation of liners, and investigation of ground water table interaction with lagoons after irrigation season began.
- Construction of new lagoons with sizing and liners that exceed state standards.
- Improvement in overall manure management.
- Establishment of a nutrient management plan.
- Severing and plugging of buried pipelines to eliminate potential off-site water drainage.

ISDA conducted a third sampling event in November 2003. Sampling included all past analyses in addition to expansion of pharmaceutical testing. A majority of wells were also tested for human waste indicators, such as caffeine and estradiol, to aid in determination of septic system impacts on ground water contamination. Results of November 2003 sampling are pending.

Recommendations

ISDA recommends continued monitoring in the project area.

Testing should include, but not be limited to:

- Continued ground water monitoring for nutrients, common ions, and bacteria.
- Continued isotope testing to determine possible NO_3-N sources.
- Additional static water level measurement.
- ISDA effectiveness monitoring as facility improvements, BMP programs, and/or regulatory changes are implemented.
- Installation of monitoring wells. ISDA and the Idaho Department of Environmental Quality (IDEQ) are currently working to implement a monitoring well work plan.
- Identification of land application areas.

ISDA further recommends that measures to reduce nitrate impacts on ground water be addressed and implemented. ISDA recommends that:

- Growers and agrichemical professionals conduct nutrient, pesticide, and irrigation water management evaluations.
- Producers follow the Idaho Agricultural Pollution Abatement Plan and Natural Resources Conservation Service Nutrient Management Standard.
- Homeowners assess lawn and garden practices, especially near wellheads.
- Local residents assess animal waste management practices.
- State and local agencies assess impacts from private septic systems.

ISDA will continue to work with the regulated facilities to protect ground water. ISDA recommends that the Weiser River Soil Conservation District (SCD) lead an agricultural response related to unregulated nonpoint sources of pollutants. The Weiser River SCD should work with local agrichemical professionals, landowners, agencies, and the IDEQ Weiser Nitrate Ground Water Protection Committee to implement this process and seek funding to support these efforts. ISDA will support these local partners in seeking funding and implementing a comprehensive program.

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